Applying a multi-objective optimization approach for design of a General Purpose Heat Source (GPHS)

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Abstract:

The General Purpose Heat Source is a radioactive heat source designed for provides electricity and heat for space missions. It is packaged as stackable module containing and protecting a nuclear fuel fabricated into ceramic pellets. The radioactive material poses potential hazards in case of a mission accident. For this reason, safety is treated as an inherent feature of design. The pellets are encapsulated in a refractory metal clad, and are encased within nested layers of composite materials. The performance and safety of the radioisotope power source depend in part on the dimensions and mechanical properties of the many protection layers surrounding the fuel. Safety testing of nuclear power source components must be used to understand their responses for a variety of accident scenarios. However, the potential accident scenarios that can arise are more extensive than can be tested. Therefore, the safety analysis relies on numerical modelling to simulate safety tests which are very difficult to achieve experimentally.
A finite element model was developed to investigate the response of a heat source under impact loading. The objective of this study is to obtain light heat source design able to withstand impact against rigid bodies. In order to obtain such a design, geometric optimization method is used with parametric finite element analysis. Design exploration from ANSYS Workbench is used in the study. Variations in the design parameters (thicknesses of the protective layers) were studied. The optimization study provided response charts of the different design variables on the output. Sensitivity analysis of the input variables helped in identifying the importance of each design variable and their respective effects on the output. Finally the different design points were rated based on a goal-driven optimization study and the best design is chosen.

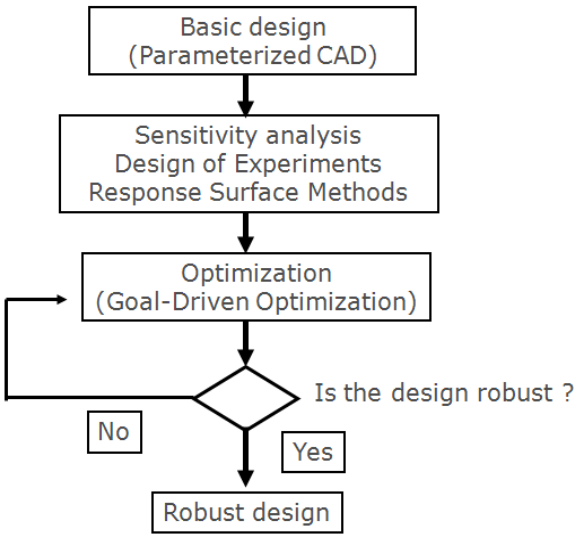

Fig1: Optimization approach used in the GPHS design analysis.

References

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